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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: Application of:		Group Art Unit: 1725
Applicant:	Vinod Philip	Examiner: Jonathan J. Johnson
Serial No.:	10/666,203	Atty. Docket: 2003P13549US
Filed:	09/18/2003	Confirmation No.: 8293
Title:	HIGH STRENGTH DIFFUSION BRAZING UTILIZING NANO-POWDERS	

Mail Stop Appeal Brief - Patent
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

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This cover sheet (1 page)
Appellant's Brief under 37 CFR 41.37 including Appendices (17 pages)

David G. Maire 9/18/2007

David G. Maire, Reg. No. 34,865 Date

Beusse Wolter Sanks Mora & Maire, P.A.
390 North Orange Ave., Suite 2500
Orlando, FL 32801
telephone: 407-926-7704

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Sir:

APPELLANT'S BRIEF UNDER 37 CFR 41.37

This brief is in furtherance of the Notice of Appeal filed in this application on 18 July 2007.

The fee required for the filing of an Appellant's Brief was previously paid on 12 July 2006 upon the filing of the first Appellant's Brief. Upon receipt of that first brief, the Examiner elected to reopen prosecution, resulting in the necessity for the filing of a second appeal and this brief. Accordingly, no fee is necessary for the filing of this paper.

1. REAL PARTY IN INTEREST - 37 CFR 41.37(c)(1)(i)

The real party in interest in this Appeal is the assignee Siemens Power Generation, Inc.

2. RELATED APPEALS AND INTERFERENCES - 37 CFR 41.37(c)(1)(ii)

There is no other appeal, interference or judicial proceeding that is related to or that will directly affect, or that will be directly affected by, or that will have a bearing on the Board's decision in this Appeal.

3. STATUS OF CLAIMS - 37 CFR 41.37(c)(1)(iii)

Claims pending: 1-9 and 24-26.

Claims cancelled: 10-23.

Claims withdrawn but not cancelled: 2-4 and 7-9

Claims allowed: none.

Claims objected to: none.

Claims rejected: 1, 5, 6 and 24-26.

The claims on appeal are 1, 5, 6 and 24-26.

4. STATUS OF AMENDMENTS - 37 CFR 41.37(c)(1)(iv)

No amendment has been filed subsequent to the final rejection.

5. SUMMARY OF THE CLAIMED SUBJECT MATTER- 37 CFR 41.37(c)(1)(v)

This invention relates generally to an improved braze material 10 for joining superalloy materials, as illustrated in the sole Figure of the application.

Independent claim 1 is specifically directed to a braze material 10 for diffusion brazing of an article 12 formed of a superalloy material, the braze material including a carrier 18 and superalloy filler particles 14, as described in the specification at page 3, lines 10-24. The superalloy filler particles 14 include a first portion of nano-sized particles and a second portion of micron-sized particles, as described at page 4, lines 13-17.

6. GROUNDS OF REJECTION TO BE REVIEWED UPON APPEAL - 37 CFR 41.37(c)(1)(vi)

A. Claims 1, 5 and 6 are rejected under 35 USC 112, first paragraph as failing to comply with the written description requirement.

B. Claims 1 and 26 are rejected under 35 USC 102(b) as being anticipated by United States patent 6,520,401 (hereinafter Miglietti).

C. Claims 5 and 6 are rejected under 35 USC 103(a) as being unpatentable over Miglietti, and further in view of WO 96/06700 (hereinafter Linden).

D. Claims 1, 5, 6, 24 and 25 are rejected under 35 USC 103(a) as being unpatentable over Miglietti in view of Linden.

7. ARGUMENT 37 CFR 41.37(c)(1)(vii)

A. Arguments regarding rejection of claims 1, 5 and 6 under 35 USC 112:

The Examiner finds that there is no support in the specification for the entire range of either nano-sized particles or micron-sized particles as included in claims 1, 5 and 6, but rather that the specification has support only for the particular ranges specifically described in various embodiments disclosed in the specification.

First, this rejection is necessarily self-defeating, since the objected-to terms "nano-sized" and "micron-sized" were used in the originally filed specification; and thus, no matter what definition the Examiner chooses to apply to these terms in the claims, that same definition should be applied to their use in the specification, thereby providing the required showing that the Appellant had possession of the claimed range.

Furthermore, the terms "nano-sized" and "micron-sized" are used at many locations in the specification in a broad sense without any particular sub-range limitation, thereby showing the Appellant had possession of the broadly claimed ranges. For example, at page 4, lines 1-2 it is stated that "The present inventor has innovatively recognized the advantage of utilizing nano-sized particles in a braze material mix in order to eliminate or to reduce the amount of melting point depressant necessary to achieve a desired lower incipient melting temperature." At page 4, lines 13-15, the specification reads "In yet other embodiments, a combination of nano-sized and micron-sized superalloy filler particles may be used..." Since the Examiner admits that these

terms as used in the claims are broad enough to cover the entire range of nano-sized particles and micron-sized particles, then that same interpretation must be applied to the originally filed specification, thereby showing that the Appellant was in possession of the invention as claimed.

The present specification clearly describes particles having two distinct size ranges: the larger micron-sized particles and the smaller nano-sized particles. Evidence of the common understanding of these terms was provided to the Office in the form of three Internet web pages submitted with the Response under 37 CFR 1.111 filed on 18 January 2007. Copies of these web pages are included herewith in the Evidence Appendix where: 1) nanotechnology is defined as the field of science involving the control of matter on a scale smaller than one micrometer (see "Nanotechnology - Wikipedia"); 2) nanotechnology is used to describe research where the characteristic dimensions are less than about 1,000 nanometers (see "Nanotechnology - Created by Dr. Ralph Merkle) ; and 3) where the prefix "nano" is shown to range from 0.000,000,001 meter to 0.000,001 meter and "micro" is shown to range from 0.000,001 meter to 0.001 meter (page 3 of 24 of "A Dictionary of Units" presented herein as page 5 of 6 of the Evidence Appendix). Thus, the Appellant's use of the broad terms "nano-sized" and micron-sized" in the specification is well understood in the art and provides support the claimed broad range.

Further, while the present specification clearly uses the terms micron-sized and nano-sized as being exclusive of each other, it does not suggest that only particular sub-ranges of nano-sizes and micron-sizes are enabled. For example, beginning at page 4, line 3, it is explained that:

> *It is recognized that any typical powder sample set may have an incidental number of particles in the nano-size range. The present invention contemplates particles that are specifically produced to be nano-sized, i.e. to have a cross-sectional dimension in the nano-size range. In one embodiment, the filler mix used to form a brazing mixture may include only a nano-sized superalloy filler powder ... In yet other embodiments, a combination of nano-sized and micron-sized superalloy filler particles may be used ...*

The present specification goes on to describe particular embodiments that fall within

these broad ranges. Nowhere does the specification suggest that the broad terms "nano-sized" and "micro-sized" should be limited to the specific sub-ranges described in the particular embodiments used to illustrate the invention. Without such restriction, one skilled in the art would understand that the Appellant was broadly describing his invention as including the entire nano and micron size ranges. The last paragraph of the specification makes it clear that no such limitations should be inferred into the specification description when it states at page 12, lines 6-7 that "...such embodiments are provided by way of example only."

Thus, there is adequate support in the specification for the broadly claimed size ranges, and the claim rejections under 35 USC 112, second paragraph, are improper and should be reversed.

B. Arguments regarding rejection of claims 1 and 26 under 35 USC 102(b) as being anticipated by Miglietti:

While the Examiner admits that Miglietti discloses only 40 micron powder, he bases this rejection on an interpretation of 40 microns as being 40,000 nanometres and therefore as anticipating the claim limitation of "nano-sized particles." However, the terms of the claims must be interpreted in accordance with their use in the specification, and it is inconsistent with the specification and the common use of the term "nano-sized" to interpret 40 microns as being a nano-sized dimension.

The fact that one skilled in the art would not interpret a 40 micron dimension as being "nano-sized" is evidenced by the three Internet web pages included herewith in the Evidence Appendix and discussed above. See for example page 3 of 24 of "A Dictionary of Units" presented herein as page 5 of 6 of the Evidence Appendix wherein the term nano is identified as being applied only to sizes that are smaller than micro sizes. The term "nano-sized" of claim 1 should be interpreted in accordance with the specification which is consistent with the common use of that term to read on dimensions only smaller than 1 micron. Furthermore, all of the nano-sized particle embodiments described in the specification are less than 1,000 nm (i.e. less than a micron), thereby providing no basis for interpreting the claim term "nano-sized" to read on particles having a size of 40 microns (40,000 nanometres). When considering distances that are normally measured in a common large unit of measurement, it is not customary to use extremely

large values of a smaller unit of measurement. To illustrate the inappropriateness of the Examiner's position is to consider an analogy where someone would refer to Denver, Colorado, as the "5,280 foot high city." Clearly, no court or person skilled in the art would interpret the term "nano-sized" as used in the present specification or as used in claim 1 to read on a 40 micron (40,000 nanometres) particle. Thus, the cited prior art does not support the rejection of independent claim 1 or its dependent claim 26 under 35 USC 102, and the rejections should be reversed.

<u>C and D. Arguments regarding the rejection of claims 1, 5, 6, 24 and 25 under 35 USC 103(a) as being unpatentable over Miglietti and further in view of Linden:</u>

The Appellant argues all of the claims rejected under 35 USC 103 as a group.

1) Independent claim 1 and each of the dependent claims 5, 6, 24 and 25 include the limitations of having both nano-sized superalloy particles and micron-sized superalloy particles in a braze material for diffusion brazing.

Miglietti teaches the use of two different sizes of alloy powder 14 to fill a crack 10 in a diffusion brazing process. The alloy powder 14 is joined into a brazed joint by the melting and subsequent infiltration of an overlying low melting point braze material 16. Note that the alloy material is the basic structural material and the braze material is the lower temperature material used to adhere the alloy material particles together into a solid joint. Both of the alloy particle sizes of Miglietti are micron-sized particles, specifically 40 microns and 150 microns, as described at column 6, lines 17-21 of Miglietti. Miglietti teaches the use of hafnium or zirconium in lieu of boron melting point depressant in the overlying braze material 16.

The Examiner suggests that it would have been obvious to replace the 40 micron <u>alloy particles</u> of Miglietti with nano-scale particles in order to reduce the melting point of the <u>braze material</u> and to form a stronger bond, citing page 47 of Linden. It is clear from this language that the Examiner is confusing the structural alloy material and the infiltrating braze material, since no change in the alloy particles would effect the melting point of the braze material. Miglietti fails to teach or to suggest any change in the alloy powder 14, itself, in order to reduce the amount of melting point depressant. Rather, it is the braze material 16 that is the source of the boron melting point depressant that Miglietti desires to reduce.

Linden teaches that nano-sized particles melt at a lower temperature than larger particles, but there is no teaching or motivation in either Miglietti or Linden or in their combination to replace the depressant-containing <u>braze material</u> 16 of Miglietti with <u>alloy material</u>. On this basis alone the rejections under 35 USC 103 should be reversed.

2) Furthermore, claim 1 includes the limitations of both nano-sized and micron-sized alloy particles, and the combined teaching of Miglietti and Linden is devoid of any such teaching. There is no motivation in either Miglietti or Linden or their combination to reduce the size of only a <u>portion</u> of the allow powder to the nano-scale level in order to affect the amount of melting point depressant that is used. Such changes are motivated only by the Appellant's invention, thereby providing a second basis for overturning the rejections under 35 USC 103.

3) Finally, and perhaps most importantly, the Examiner's suggested substitution of nano-sized particles of Linden in place of the fine grain (40 micron) particles of Miglietti would destroy the functionality of the very hybrid structure desired by Miglietti and described at column 6, line 24-26. The combination of both course-grained structures and fine-grained structures is achieved in Miglietti because the alloy particles do not melt, or at least they do not melt completely. The larger (150 micron) and smaller (40 micron) particles are fused together in a matrix of the melted braze material 16 to form the composite material 18. Miglietti teaches that it is desired to maintain the composite material as a mixed or hybrid structure in order to take advantage of <u>both</u> fine and course structures. The substitution of nano-sized particles of Linden for the 40 micron particles of Miglietti, as suggested by the Examiner, would result in the smaller particles melting, thereby leaving the resulting composite material 18 with only a single grain size of the 150 micron particles joined by the mixed melt of the braze material 16 and the melted nano-sized particles. Thus, the intended function of the hybrid structure desired by Miglietti is destroyed by the combination of Linden with Miglietti that is proposed by the Examiner. The courts have consistently held that when a rejection under 35 USC 103 is based upon a modification of a reference that destroys the intent, purpose or function of the invention disclosed in the reference, such a proposed modification is not proper and the *prima facie* case of obviousness cannot be properly made.

Accordingly, the Appellant respectfully requests that the Board reverse the rejections of claims 1, 5, 6, 24 and 25 under 35 USC 103.

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8. CLAIMS APPENDIX - 37 CFR 41.37(c) (1) (viii).

A copy of the claims involved in this appeal is attached as a claims appendix under 37 CFR 41.37(c) (1) (viii).

9. EVIDENCE APPENDIX - 37 CFR 41.37(c) (1) (ix)

Attached are copies of each of the three Internet web pages entered into the record on 18 January 2007 along with the applicant's response under 35 USC 1.111.

10. RELATED PROCEEDINGS APPENDIX - 37 CFR 41.37(c)(1) (x)

None is required under 37 CFR 41.37(c)(1) (x).

Respectfully submitted,

Dated: 9/18/2007

By: David G. Maire

David G. Maire
Registration No. 34,865
(407) 926-7704

Beusse Wolter Sanks Mora & Maire, P.A.
390 N. Orange Ave., Suite 2500
Orlando, FL 32801

APPENDIX OF CLAIMS ON APPEAL

1. A braze material for diffusion brazing of an article formed of a superalloy material, the braze material comprising a carrier and superalloy filler particles, the superalloy filler particles comprising a first portion of nano-sized particles and a second portion of micron-sized particles.

5. The braze material of claim 1, further comprising braze alloy particles having a melting point temperature below that of a bulk melting temperature of the superalloy material of the micron-sized superalloy filler particles and above that of the nano-sized superalloy filler particles.

6. The braze material of claim 5, wherein a weight ratio of the nano-sized superalloy filler particles to the micron-sized constituents is at least 70/30.

24. The braze material of claim 1, wherein the nano-sized particles comprise a size range of 10-100 nm and the micron-sized particles comprise a size range of 45-100 microns.

25. The braze material of claim 1, wherein the nano-sized particles comprise a size range such that they exhibit a melting temperature at least 50 °F. less than a melting temperature of the micron-sized particles.

26. The braze material of claim 1 being substantially free of boron and silicon.

RELATED PROCEEDINGS APPENDIX

None.

EVIDENCE APPENDIX

Six pages printed from the Internet and entered as evidence via the applicant's response under 37 CFR 1.111 dated 18 January 2007 are attached following this page.

Nanotechnology

From Wikipedia, the free encyclopedia

Molecular gears from a NASA computer simulation.

Nanotechnology (sometimes referred to as **nanofabrication**[1] (http://whatis.techtarget.com/definition/0,,sid9_gci518307,00.html))is a field of applied science and technology covering a broad range of topics. The main unifying theme is the control of matter on a scale smaller than one micrometre, as well as the fabrication of devices on this same length scale. It is a highly multidisciplinary field, drawing from fields such as colloidal science, device physics, and supramolecular chemistry. Much speculation exists as to what new science and technology might result from these lines of research. Some view nanotechnology as a marketing term that describes pre-existing lines of research.

Despite the apparent simplicity of this definition, nanotechnology actually encompasses diverse lines of inquiry. Nanotechnology cuts across many disciplines, including colloidal science, chemistry, applied physics, biology. It could variously be seen as an extension of existing sciences into the nanoscale, or as a recasting of existing sciences using a newer, more modern term. Two main approaches are used in nanotechnology: one is a "bottom-up" approach where materials and devices are built from molecular components which assemble themselves chemically using principles of molecular recognition; the other being a "top-down" approach where nano-objects are constructed from larger entities without atomic-level control.

The impetus for nanotechnology has stemmed from a renewed interest in colloidal science, coupled with a new generation of analytical tools such as the atomic force microscope (AFM) and the scanning tunneling microscope (STM). Combined with refined processes such as electron beam lithography, these instruments allow the deliberate manipulation of nanostructures, and in turn led to the observation of novel phenomena. Nanotechnology is also an umbrella description of emerging technological developments associated with sub-microscopic dimensions. Despite the great promise of numerous nanotechnologies such as quantum dots and nanotubes, real applications that have moved out of the lab and into the marketplace have mainly utilized the advantages of colloidal nanoparticles in bulk form, such as suntan lotion, cosmetics, protective coatings, and stain resistant clothing.

Contents

Nanotechnology

Hosted by zyvex

Created by Dr. Ralph Merkle

www

RECENT NEWS:

- Sample chapters and an extended table of contents for Drexler's technical book, *Nanosystems: Molecular Machinery, Manufacturing, and Computation* are now available at his website, e-drexler.com.
- Nanorex is designing and modeling molecular machine components.
- Foresight's Nanotechnology Roadmap Initiative
- New book on *Kinematic Self-Replicating Machines* by Robert Freitas and Ralph Merkle now available.

The next few paragraphs provide a brief introduction to the core concepts of molecular nanotechnology, followed by links to further reading.

Manufactured products are made from atoms. The properties of those products depend on how those atoms are arranged. If we rearrange the atoms in coal we can make diamond. If we rearrange the atoms in sand (and add a few other trace elements) we can make computer chips. If we rearrange the atoms in dirt, water and air we can make potatoes.

Todays manufacturing methods are very crude at the molecular level. Casting, grinding, milling and even lithography move atoms in great thundering statistical herds. It's like trying to make things out of LEGO blocks with boxing gloves on your hands. Yes, you can push the LEGO blocks into great heaps and pile them up, but you can't really snap them together the way you'd like.

In the future, nanotechnology will let us take off the boxing gloves. We'll be able to snap together the fundamental building blocks of nature easily, inexpensively and in most of the ways permitted by the laws of physics. This will be essential if we are to continue the revolution in computer hardware beyond about the next decade, and will also let us fabricate an entire new generation of products that are cleaner, stronger, lighter, and more precise.

It's worth pointing out that the word "nanotechnology" has become very popular and is used to describe many types of research where the characteristic dimensions are less than about 1,000 nanometers. For example, continued improvements in lithography have resulted in line widths that are less than one micron: this work is often called "nanotechnology." Sub-micron lithography is clearly very valuable (ask anyone who uses a computer!) but it is equally clear that conventional lithography will not let us build semiconductor devices in which individual dopant atoms are located at specific lattice sites. Many of the exponentially improving trends in computer hardware capability have remained steady for the last 50 years. There is fairly widespread belief that these trends are likely to continue for at least another several years, but then conventional lithography starts to reach its limits.

A Dictionary of Units

by ***Frank Tapson***

This provides a summary of most of the units of measurement to be found in use around the world today (and a few of historical interest), together with the appropriate conversion factors needed to change them into a 'standard' unit of the SI.

The units may be found either by looking under the in which they are used, (length energy etc.)	**category**
or by picking one unit from an alphabetically ordered	**list of units.**
There is an outline of the	**S I system,**
a list of its 7 basic	**definitions,**
some of its	**derived units,**
together with a list of all the	**S I prefixes,**
and some of the rules and conventions for	**its usage.**
On the subject of measures generally, there is a short	**historical note.**
Then there are descriptions of the	**Metric system,**
and the	**U K (Imperial) system,**
followed by statements on the implementation of	**'metrication' in the U K,**
and then the	**U S system of measures.**
At the bottom of this document is a	**list of other sources,**
and also some links to other	**Web sites.**
Finally there are some	**notes on this material.**

A more extensive (3-part) version of this dictionary will be found at www.ex.ac.uk/trol/dictunit/

The Systeme International [S I]

Le Systeme international d'Unites officially came into being in October 1960 and has been officially recognised and adopted by nearly all countries, though the amount of actual usage varies considerably. It is based upon 7 principal units, 1 in each of 7 different categories -

Category	Name	Abbrev.
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Definitions of these basic units are given. Each of these units may take a prefix. From these basic units many other units are derived and named.

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Definitions of the Seven Basic S I Units

metre [m]
The metre is the basic unit of length. It is the distance light travels, in a vacuum, in 1/299792458*th* of a second.

kilogram [kg]
The kilogram is the basic unit of mass. It is the mass of an international prototype in the form of a platinum-iridium cylinder kept at Sevres in France. *It is now the only basic unit still defined in terms of a material object, and also the only one with a prefix[kilo] already in place.*

second [s]
The second is the basic unit of time. It is the length of time taken for 9192631770 periods of vibration of the caesium-133 atom to occur.

ampere [A]
The ampere is the basic unit of electric current. It is that current which produces a specified force between two parallel wires which are 1 metre apart in a vacuum.*It is named after the French physicist Andre Ampere (1775-1836).*

kelvin [K]
The kelvin is the basic unit of temperature. It is 1/273.16*th* of the thermodynamic temperature of the triple point of water. *It is named after the Scottish mathematician and physicist William Thomson 1st Lord Kelvin (1824-1907).*

mole [mol]
The mole is the basic unit of substance. It is the amount of substance that contains as many elementary units as there are atoms in 0.012 kg of carbon-12.

candela [cd]
The candela is the basic unit of luminous intensity. It is the intensity of a source of light of a specified frequency, which gives a specified amount of power in a given direction.

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Derived Units of the S I

From the 7 basic units of the SI other units are derived for a variety of purposes. Only a few of are explained here as examples, there are many more.

farad [F]
The farad is the SI unit of the capacitance of an electrical system, that is, its capacity to store electricity. It is a rather large unit as defined and is more often used as a microfarad. *It is named after the English chemist and physicist Michael Faraday (1791-1867).*

hertz [Hz]
The hertz is the SI unit of the frequency of a periodic phenomenon. One hertz indicates that 1 cycle of the phenomenon occurs every **second**. For most work much higher frequencies are needed such as the kilohertz [kHz] and megahertz [MHz]. *It is named after the German physicist Heinrich Rudolph Hertz (1857-94).*

joule [J]
The joule is the SI unit of work or energy. One joule is the amount of work done when an applied force of 1 **newton** moves through a distance of 1 **metre** in the

direction of the force. *It is named after the English physicist James Prescott Joule (1818-89).*

newton [N]
The newton is the SI unit of force. One newton is the force required to give a mass of 1 **kilogram** an acceleration of 1 **metre** per **second** per **second.** *It is named after the English mathematician and physicist Sir Isaac Newton (1642-1727).*

ohm [Ω]
The ohm is the SI unit of resistance of an electrical conductor. Its symbol, is the capital Greek letter 'omega'. *It is named after the German physicist Georg Simon Ohm (1789-1854).*

pascal [Pa]
The pascal is the SI unit of pressure. One pascal is the pressure generated by a force of 1 **newton** acting on an area of 1 square **metre.** It is a rather small unit as defined and is more often used as a kilopascal [kPa]. *It is named after the French mathematician, physicist and philosopher Blaise Pascal (1623-62).*

volt [V]
The volt is the SI unit of electric potential. One volt is the difference of potential between two points of an electical conductor when a current of 1 **ampere** flowing between those points dissipates a power of 1 **watt.** *It is named after the Italian physicist Count Alessandro Giuseppe Anastasio Volta (1745-1827).*

watt [W]
The watt is used to measure power or the rate of doing work. One watt is a power of 1 **joule** per **second.** *It is named after the Scottish engineer James Watt (1736-1819).*

Note that prefixes may be used in conjunction with any of the above units.
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The Prefixes of the S I

The S I allows the sizes of units to be made bigger or smaller by the use of appropriate prefixes. For example, the electrical unit of a watt is not a big unit even in terms of ordinary household use, so it is generally used in terms of 1000 watts at a time. The prefix for 1000 is *kilo* so we use kilowatts[kW] as our unit of measurement. For makers of electricity, or bigger users such as industry, it is common to use megawatts[MW] or even gigawatts[GW]. The full range of prefixes with their [symbols or abbreviations] and their multiplying factors *which are also given in other forms* is

```
yotta  [Y]  1 000 000 000 000 000 000 000 000      = 10^24
zetta  [Z]  1 000 000 000 000 000 000 000          = 10^21
exa    [E]  1 000 000 000 000 000 000              = 10^18
peta   [P]  1 000 000 000 000 000                  = 10^15
tera   [T]  1 000 000 000 000                      = 10^12
giga   [G]  1 000 000 000            (a thousand millions = a billion)
mega   [M]  1 000 000                (a million)
kilo   [k]  1 000                    (a thousand)
hecto  [h]  100                      (a hundred)
deca   [da] 10                       (ten)
            1
deci   [d]  0.1                      (a tenth)
centi  [c]  0.01                     (a hundredth)
milli  [m]  0.001                    (a thousandth)
micro  [μ]  0.000 001                (a millionth)
nano   [n]  0.000 000 001            (a thousand millionth)
```

```
pico   [p] 0.000 000 000 001                              = 10^-12
femto  [f] 0.000 000 000 000 001                          = 10^-15
atto   [a] 0.000 000 000 000 000 001                      = 10^-18
zepto  [z] 0.000 000 000 000 000 000 001                  = 10^-21
yocto  [y] 0.000 000 000 000 000 000 000 001              = 10^-24
```

[µ] the symbol used for **micro** is the Greek letter known as 'mu'
Nearly all of the S I prefixes are multiples (kilo to yotta) or sub-multiples (milli to yocto) of 1000. However, these are inconvenient for many purposes and so **hecto, deca, deci,** and **centi** are also used. **deca** also appears as **deka [da]** or **[dk]** in the USA and Contintental Europe. So much for standards!
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Conventions of Usage in the S I

There are various rules laid down for the use of the SI and its units as well as some observations to be made that will help in its correct use.

- Any unit may take only ONE prefix. For example 'millimillimetre' is incorrect and should be written as 'micrometre'.
- Most prefixes which make a unit bigger are written in capital letters (M G T etc.), but when they make a unit smaller then lower case (m n p etc.) is used. Exceptions to this are the kilo [k] to avoid any possible confusion with kelvin [K]; hecto [h]; and deca [da] or [dk]
- It will be noted that many units are eponymous, that is they are named after persons. This is always someone who was prominent in the early work done within the field in which the unit is used. Such a unit is written all in lower case (newton, volt, pascal etc.) when named in full, but starting with a capital letter (N V Pa etc.) when abbreviated. An exception to this rule is the litre which, if written as a lower case 'l' could be mistaken for a '1' (one) and so a capital 'L' is allowed as an alternative. It is intended that a single letter will be decided upon some time in the future when it becomes clear which letter is being favoured most in use.
- Units written in abbreviated form are NEVER pluralised. So 'm' could always be either 'metre' or 'metres'. 'ms' would represent 'millisecond'.
- An abbreviation (such as J N g Pa etc.) is NEVER followed by a full-stop unless it is the end of a sentence.
- To make numbers easier to read they may be divided into groups of 3 separated by spaces (or half-spaces) but NOT commas.
- The SI preferred way of showing a decimal fraction is to use a comma (123,456) to separate the whole number from its fractional part. The practice of using a point, as is common in English-speaking countries, is acceptable providing only that the point is placed ON the line of the bottom edge of the numbers (123.456) and NOT in the middle.

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A Brief History of Measurement

One of the earliest types of measurement concerned that of length. These measurements were usually based on parts of the body. A well documented example (the first) is the